DYNAMICS OF CHARGE CLOUDS

BY

SURINDRA NATH KALRA

B.S., University of Panjab, 1946
M.S., University of Illinois, 1947

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ELECTRICAL ENGINEERING
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

URBANA, ILLINOIS

1950

DYNAMICS OF CHARGE CLOUDS

BY

SURINDRA NATH KALRA

B.S., University of Panjab, 1946
M.S., University of Illinois, 1947

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ELECTRICAL ENGINEERING
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

URBANA, ILLINOIS

1950

ACKNOWLEDGMENT

The author wishes to express his grateful appreciation of the help and guidance he has received from Professor W. J. Fry throughout his work. He is also indebted to Professor L. T. DeVore for many helpful suggestions and encouragement.

Suggestions of Professor P. W. Ketchum regarding solution of differential equations are gratefully acknowledged.

The help given to the author by his friends and colleagues in the Electrical Engineering Department is greatly appreciated.

R. UNIV. BIBLIOTHEEK LEIDEN

DYNAMICS OF CHARGE CLOUDS

The general problem of the dynamics of charge clouds in the presence of plasma is difficult to solve analytically because of the number of parameters involved. In the problem treated here the number of parameters has been reduced by considering the effects of space charge and of thermal velocities on pulses of charge in one dimensional cases.

From the two Maxwell Equations, the Dynamical Equation of Motion and the Conservation of Charge Equation, the Poisson's Equation and the Gauss' Theorem can be derived. These are sufficient to solve the one dimensional problems of effects on space charge in pulsed beams. It is assumed that at time, $t = O$ the velocity, v of all particles is zero. Three cases: (i) infinite plane parallel charge sheets, (ii) concentric spherical charge sheets, (iii) coaxial cylindrical charge sheets of infinite length, are considered separately.

For the purpose of the solution the equation of motion along the trajectory of a particle are considered. The particles are taken along a surface with the geometry of the charge sheets. In the case of the spherical sheets, this surface is concentric with the charge sheets. For the cylindrical pulses the surface is considered to be of unit length and coaxial with the charge sheets. For the parallel plane case the origin is so chosen that all the charges are symmetrically placed with respect to it. A plane passing through the origin and parallel to the faces of the charge sheets will have zero electric intensity all along it. The surface chosen in this case has one face of unit area along this plane through the origin and another of the same area parallel to it and passing through another point. The surfaces so constructed have a common property that during expansion due to space charge forces the total amount of charge contained in any one of them remains constant. The electric intensity over its face is constant and can be evaluated if the initial charge distribution is known.

The equation of motion for the plane parallel charge

sheets can, then, be written as

$$d^2\xi/dt^2 = \eta q_o/\epsilon,$$

where ξ is the displacement of the surface under consideration with respect to the origin at any time, η the charge to mass ratio for an electron, q_o the total charge enclosed by the surface and ϵ the permitivity of the medium. If ξ_o is the displacement of the surface at time $t = O$, then the solution of the above equation is

$$\xi = \eta q_o t^2/2\epsilon + \xi_O$$

If τ is defined as the time at which $\xi = 2\xi_O$, then since $q_o = \xi_O \rho_O$,

$$\tau^2 = [2\epsilon/\eta q_O]$$

It is seen that τ is independent of the initial dimensions of the charge sheet.

Next, consider more than one infinite plane parallel charge sheet. By considering the equations of motion for different planes in the charge sheets it can be shown that the spacing between successive charge sheets remains constant during the expansion of charge sheets due to space charge forces. Also, each individual pulse expands to twice its initial thickness during the time τ, as if the other pulses were not present.

For the case of concentric spherical and coaxial cylindrical pulses, for zero initial velocity, successive pulses catch up with one another and the time taken for doubling of the n*th* pulse is not independent of n.

Effects of thermal velocities of electrons inside the charge sheets have been investigated. It is shown that a velocity selection on thermionic electrons can be made, such that the thermal velocities will not have an appreciable effect on the pulsed nature of the beam.

A discussion of limits that might exist on the generation of coherent radiation from metal cavities is given. It is seen that such a limit will depend on the transit time of the beam

from the point of pulse formation to the coupling device.

Nomographs showing the expansion time of single plane parallel, spherical and cylindrical charge sheets are also given.

VITA

Surindra Nath Kalra was born at Lahore, India (now Pakistan) on May 12, 1927. He joined the Forman Christian College, Lahore of the Panjab University in 1941, and graduated from there with an Honors degree in Physics in 1946.

In September, 1946 he came to the United States and joined the Electrical Engineering Department of the University of Illinois as a graduate student. In September, 1947 he received his M.S. From September, 1947 to June, 1949 he worked as a part time graduate research assistant at the University of Illinois.

He is a member of the American Physical Society and the American Mathematical Society and an associate member of the Institute of Radio Engineers and the American Institute of Electrical Engineers.

Digitized by the Internet Archive
in 2026

https://archive.org/details/IA41549816_0078